IMPROVING THE PERFORMANCE OF FREQUENCY HOPPING ACOMMS IN A SEVERE MULTIPATH CHANNEL

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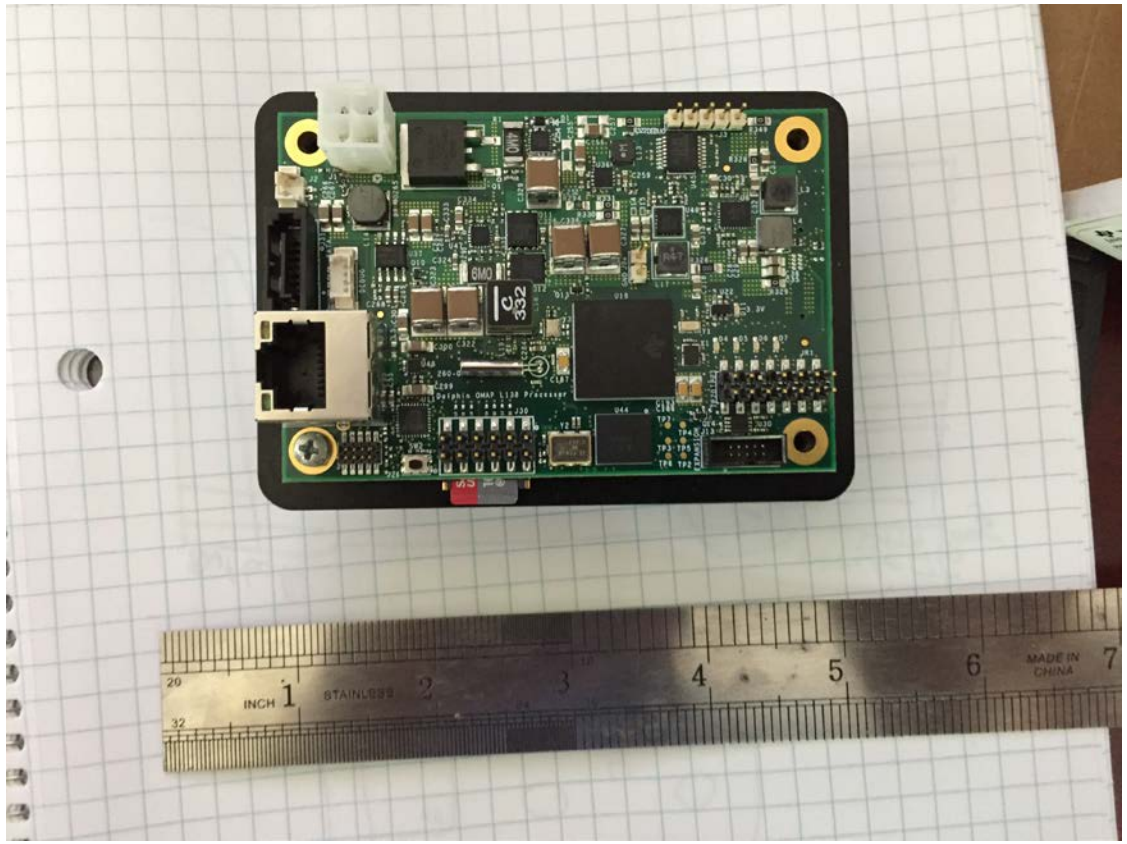
The DelResearch “Dolphin” Modem

Frequency Hopping (FH) Header or Standalone packet

- ~ 5 kHz bandwidth, 25 kHz center frequency
- 100 W transmitter
- 6.25 ms chips
- One chip/time conveying ~ ½ bit of information
- 80 bps throughput
- Non-coherent Receiver
- Very nearly the same as JANUS



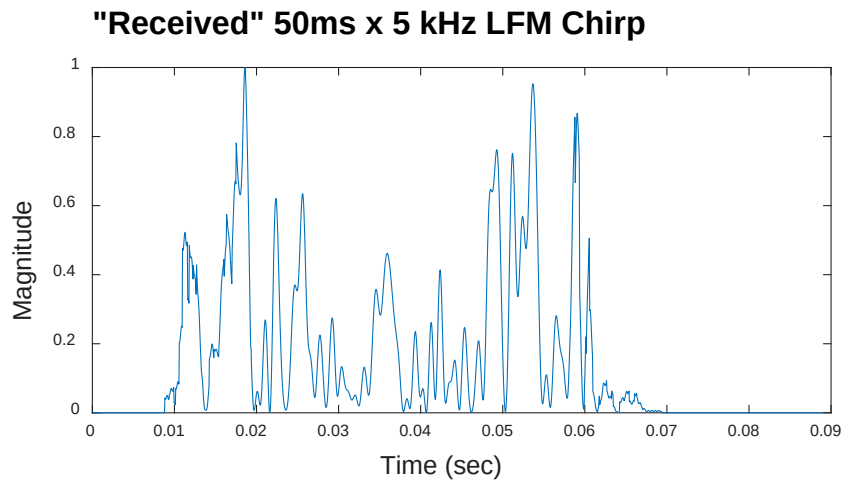
Cargo Packet

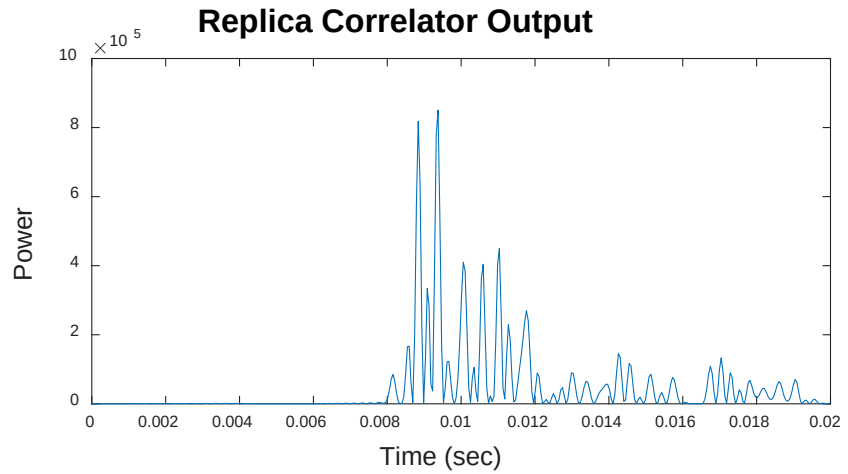
Current or planned: FH, MPSK/DFE, or Multi-channel MFSK

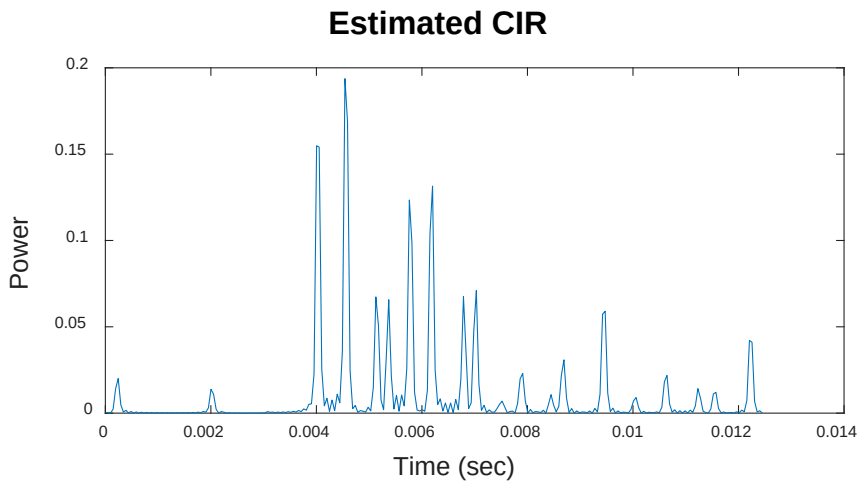
The Problem

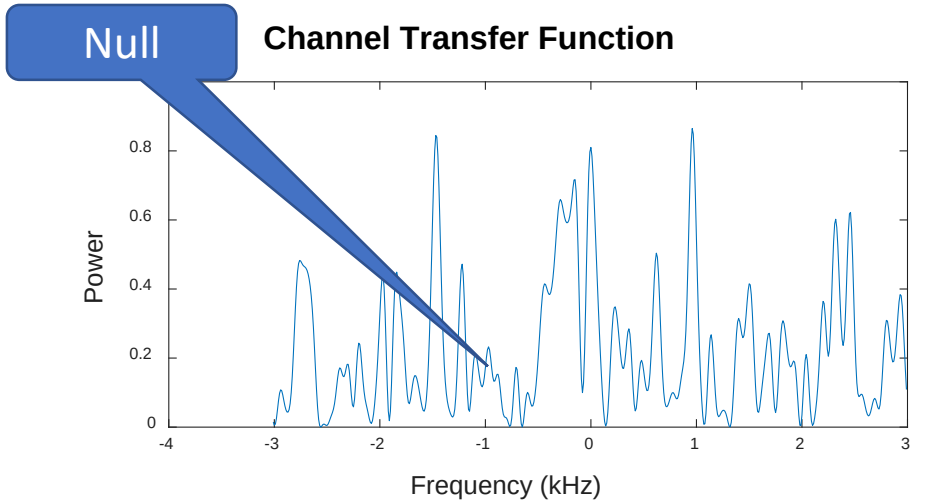
- Customer wanted a demo of 6 km range using FH signaling
- We agreed, without prior specification of the channel characteristics:
  - 100 W transmission, and the received SNR was very high – no problem!
  - This was a really stupid decision
- The test location was a lake – effectively a narrow, shallow, fjord-like fresh water body.
- We could not reach 6 km
- Why, and what to do?
- Fortunately, our transmissions included an LFM probe

A Reconstruction of the Channel (Very High SNR)









This Was An Especially Bad Channel for FH Signaling

- An FH modulation (like JANUS) only populates one frequency location per baud period.
- If there is a frequency null at the chip location, the chip is reduced or lost.
- There were just too many null locations which impacted the FH waveform

- The facts that the environment was terrible, and was not representative for future operations and use in the ocean did not impress our customer.

- It was apparent that our “FH” waveform had to transmit energy wherever the channel was not faded

Our Modified FH Waveform

The (JANUS) FH design provides the following desirable features:

1. Good asynchronous multi-access signaling
2. Constant amplitude transmission (the most basic transmitter can use an FH signal)
3. Because of (2), provides maximum power for each tonal chip

Our modified algorithm gives up on all three (but recall, we had “excess” SNR because of the high power transmitter)

The Algorithm:

Transmit the same ½ bit of information in N separate frequency locations each baud period, subject to:

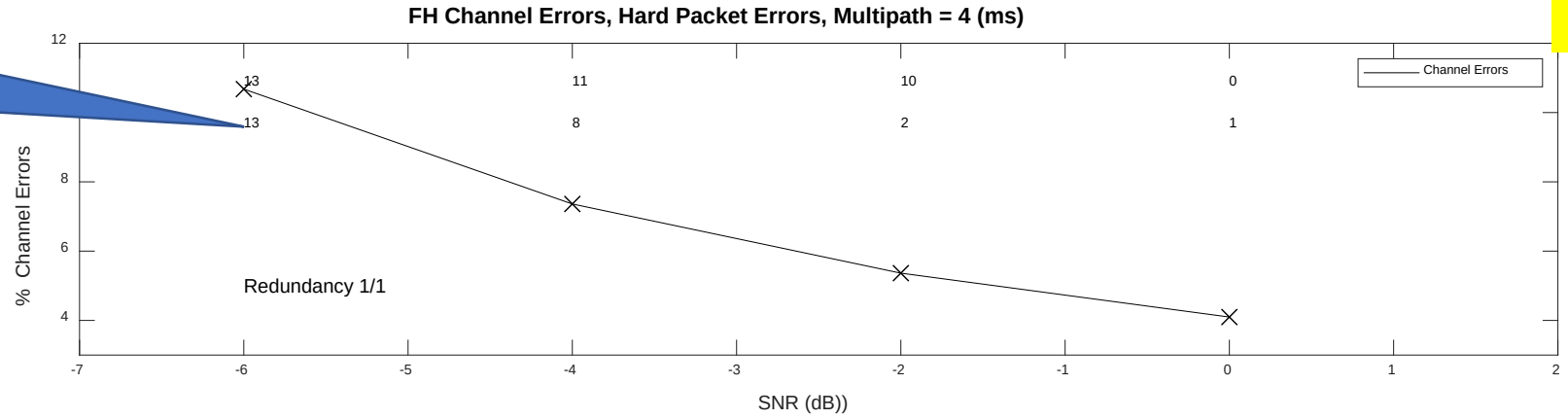
No chip in the present baud period can occupy the same frequency blocks used in the immediate previous baud period – provides worst case guard against channel spreading of 2 baud periods (12.5 ms).

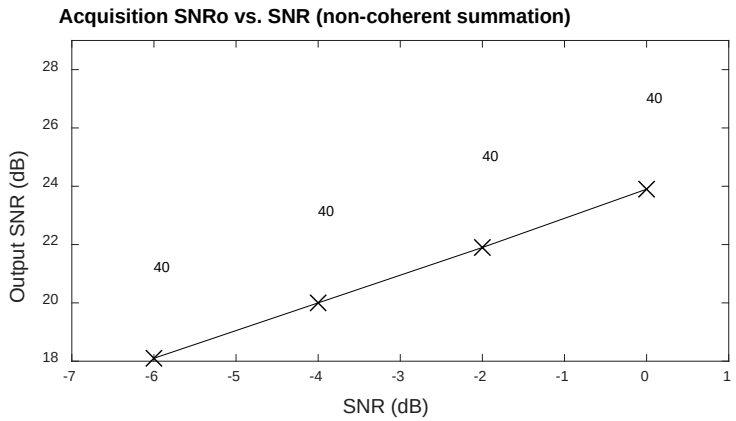
Some results from Simulation (1 of 3)

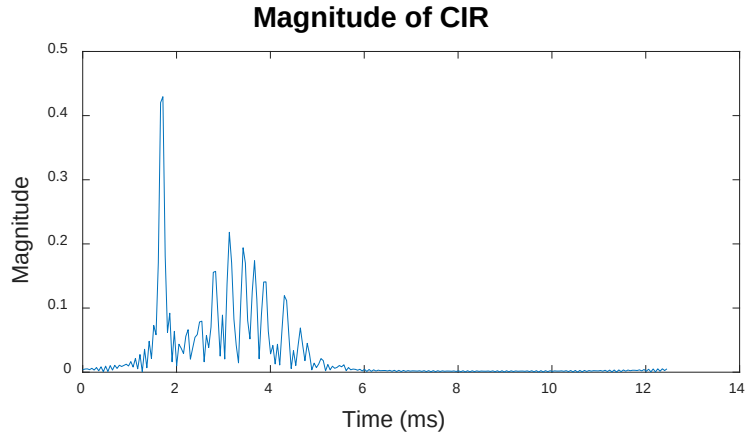
“Normal” 1 chip per baud period performance

Soft decision packet errors (out of 40)

In an AWGN channel, expect good performance to -6 or -8 dB SNR



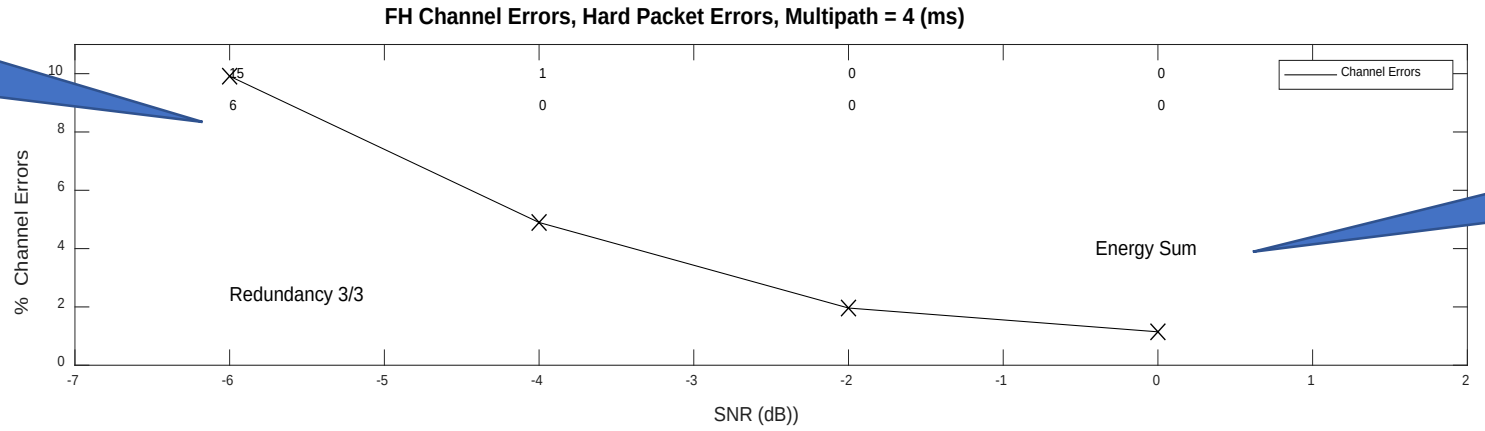




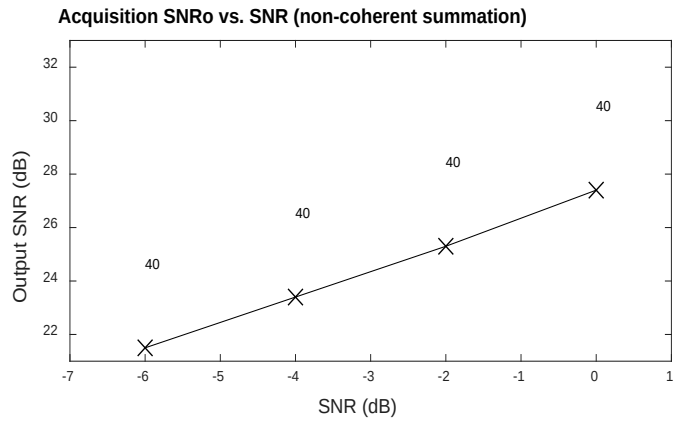
Some results from Simulation (1 of 3)

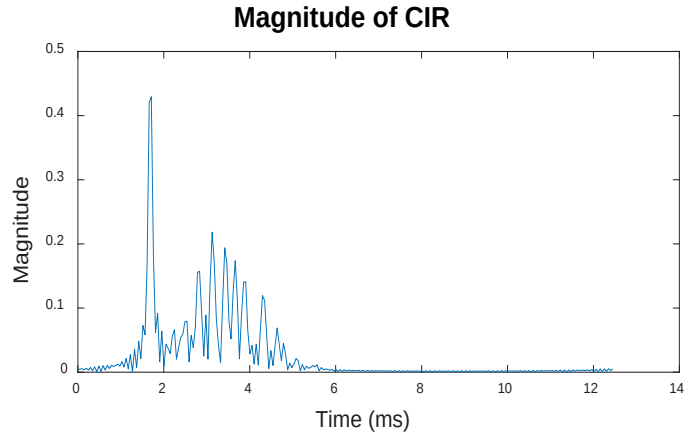
Transmit 3 tones, sum the energies at the receiver

Soft decision packet errors (out of 40)



Note

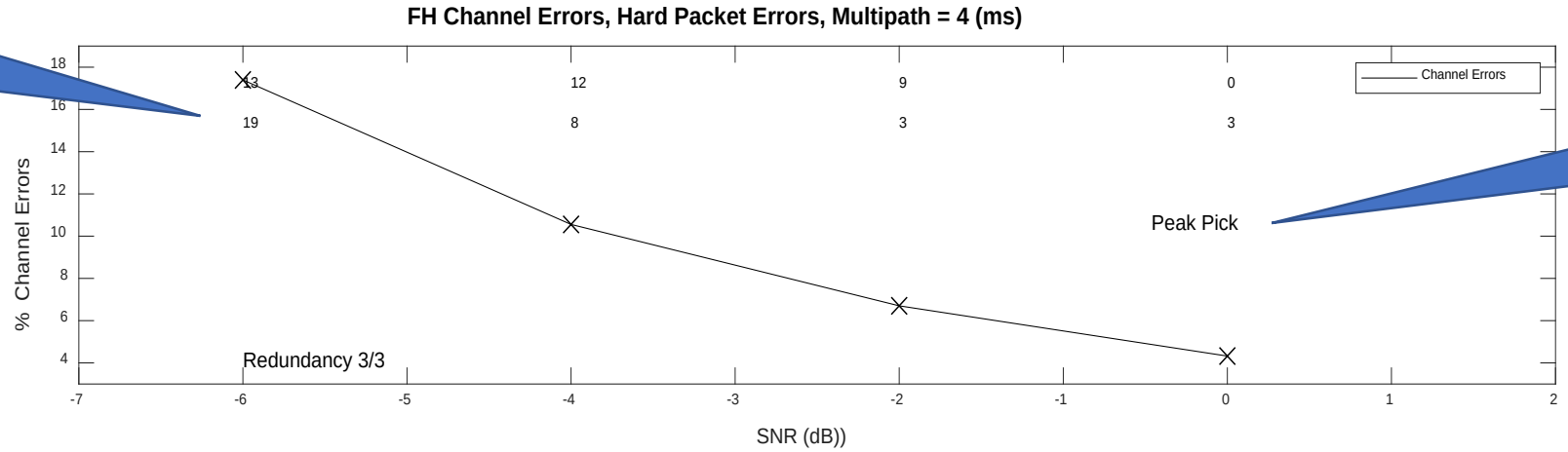




Some results from Simulation (1 of 3)

Transmit 3 tones, choose the greatest soft probability at the receiver

Soft decision packet errors (out of 40)



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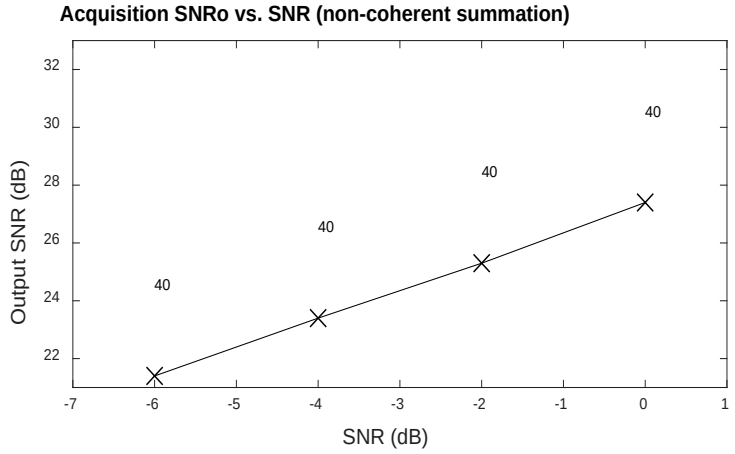

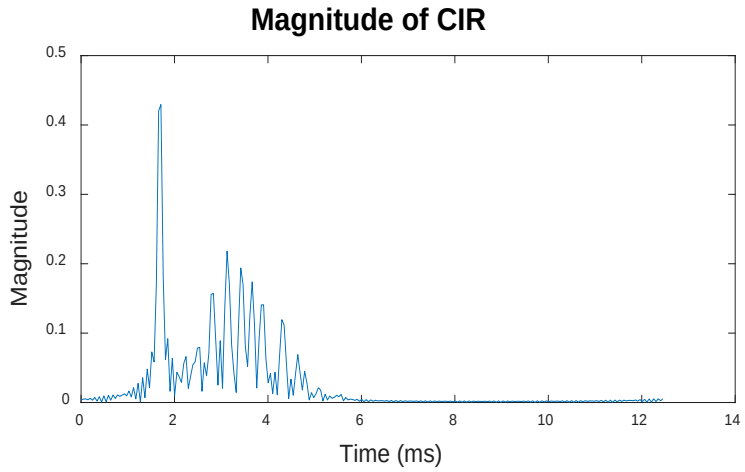

CONCLUSIONS

- Severe frequency-dependent fading can defeat a FH waveform even with high average SNR
- Transmitting multiple redundant tones at each baud period can overcome nulls in the CIR
- Summing the energy from the multiple tones outperforms “peak picking”
- Our customer wanted 6 km, we obtained over 8 km with the new algorithm

FOR LATER DISCUSSION

- What are the STANDARD methods for estimating and using environmental conditions to improve acomms performance?
  - Not necessarily soliciting dissertation-level descriptions of “the channel”
  - Looking for guidance for modem vendors and users
- For example, given the CIR of “my” channel, how would I estimate the number of FF & FB taps needed for DFE performance?
- Oatnes, VanWalree, Green, “Ambiguities in underwater acoustic communications terminology and measurement procedures” presented at UCOMMS 18, now published ??
  - Provides a defensible and highly useful measure of input/output SNR
  - Tries to codify several commonly used terms
- How does one estimate the CIR? (I personally have a problem with “replay”)
- How to estimate a rapidly changing channel scattering function?
- The IEEE editors are quietly gathering ideas, procedures, and discussions
- Is a workshop warranted? Who would organize it? Who might fund it?